

REMARKS

Claims 1-6 and 14-19 remain in the present application and have been rejected in the Final Office Action of April 25, 2005. Reconsideration and allowance of pending claims 1-6 and 14-19 in light of the following remarks are respectfully requested.

A. Rejections of Claims 1-3, 6, 14-16, and 19 Under 35 USC § 102(e) and Claims 4-5 and 17-18 Under 35 USC § 103(a)

The Examiner has rejected claims 1-3, 6, 14-16, and 19 Under 35 USC § 102(e) as being anticipated by U.S. Patent 6,740,605 to Shiraiwa et al. (hereinafter "Shiraiwa"). Further, the Examiner has rejected claims 4-5 and 17-18 Under 35 USC § 103(a) as being unpatentable over Shiraiwa. For the following reasons, Applicant respectfully submits that the pending claims are patentably distinguishable over Shiraiwa.

Shiraiwa is directed to a process for fabricating a semiconductor device that is less susceptible to performance degradation caused by hydrogen contamination. Shiraiwa discloses steps for removing unwanted hydrogen bonds after the nitride layer is formed by exposing the hydrogen bonds to ultraviolet radiation sufficient to break the bonds and annealing in an atmosphere using a gas, such as oxygen (O₂), ozone (O₃), or a source of nitrogen such as NO, N₂O, or N₂, capable of forming bonds that replace the hydrogen bonds. See Figure 12 of Shiraiwa and related description on column 11. See also column 10, line 50 through column 11, line 20.

However, as the Examiner has acknowledged, Shiraiwa does not disclose a motivation to reduce charge loss by reducing hydrogen content, but simply a desire to reduce hydrogen content to reduce contamination and a “hypothesis” that hydrogen migration into bottom or top oxide dielectric layers can cause undesirable effects by changing the “barrier height” in those layers. As the Examiner has further acknowledged on page 8, paragraph 11 of the Final Office Action, Shiraiwa is completely silent as to how hydrogen content in the nitride layer itself results in threshold voltage shifting and a desire to reduce hydrogen content in the nitride to reduce charge loss in the nitride layer itself is not taught by Shiraiwa. See, for example, column 2, lines 29-49 of Shiraiwa.

In contrast, referring to Figure 1 of the present application, due to the reduced hydrogen content in nitride layer 120, the amount of hydrogen radicals than can be freed in nitride layer 120 during subsequent programming operations is greatly reduced. Consequently, the charge loss in nitride layer 120 is significantly reduced. As a benefit, the reduction of charge loss in nitride layer 120 significantly reduces the threshold voltage shift in resulting memory cell structure 100. See, for example, the present application page 9, lines 1-6. Moreover, the present invention requires use of highly reactive nitrogen radicals in a unique CVD process to minimize number of hydrogen radicals. As stated in the present application at step 320 in flowchart 300, a unique CVD process is used to form a nitride layer having reduced charge loss over the first oxide layer. In an exemplary embodiment, a precursor comprising silane and a highly reactive form of nitrogen is used in a CVD process at a temperature of about 400 to 650° C. For example, microwave energy, or other similar processing, may be use to break up nitrogen (N₂) into a highly

reactive form of nitrogen, i.e. to form “nitrogen radicals.” With the unique CVD process described above, a nitride layer having significantly reduced hydrogen content is achieved. As discussed above, the reduced hydrogen content in the nitride layer results in a nitride layer having reduced charge loss. With reference to Figure 2, nitride layer 220 is formed over first oxide layer 215 during step 320. See, for example, the present application page 11, lines 13-22 and Figures 2 and 3. The unique technique of the present invention results in a charge storing layer having “a hydrogen content less than 1.0 atomic percent,” or a charge storing layer having “a hydrogen content between 0 and 0.5 atomic percent,” as disclosed in the present application and claimed in claims 4-5 and 17-18.

Although the Examiner has acknowledged the lack of any teaching or motivation in Shiraiwa regarding reducing charge loss through a deliberate reduction of hydrogen content in the nitride layer, the Examiner has stated that the resulting products “seem to be identical” and further the limitation of forming the charge storing layer from nitrogen radicals does not result in a patentable product. However, because a unique process using nitrogen radicals is utilized, the resulting product is also patentably distinguishable over Shiraiwa’s product. In particular, claims 4-5 and 17-18 are further distinguishable over Shiraiwa. As stated in Shiraiwa:

“The high-K dielectric material may be formed by reacting a suitable metal-containing gas, e.g., hafnium tetra-t-butoxide with a suitable oxygen-containing gas, e.g., oxygen (O₂) or nitrous oxide (N₂O). In one embodiment, the storage material may be deposited by chemical vapor deposition (CVD) methods. The CVD method may be any appropriate CVD method-known in the art for deposition of a high-K material. For example, the CVD method may be ALD (ALCVD), PECVD, MOCVD or MLD, in addition to the above-mentioned RTCVD. In one embodiment, PECVD is used to deposit the charge storage layer 30. The charge storage layer may also be deposited by other suitable methods. It will be understood that the conventional methods detailed above impart significant

hydrogen content into the charge storage layer 30 and interface 36 in the form of dielectric-hydrogen bonds. *The hydrogen content may range from greater than 3 atomic percent up to as much as 30 atomic percent, and in some cases may be greater than 8 atomic percent, and in other cases may range, from about 10 atomic percent to as much as 30 atomic percent.* For example, in conventional depositions of silicon nitride charge storage layers 30, a significant proportion of the hydrogen present at the interface 36 is present in the form of Si-H bonds, and the hydrogen content may be as high as 30 atomic percent. In one embodiment, in the next step of the present invention, shown schematically in FIG. 11 as step 1108, the process comprises irradiating the interface 36 with ultraviolet radiation. In one embodiment, the ultraviolet radiation is applied at an energy in the range of about 3 eV to about 8 eV. In one embodiment, the UV is applied at an energy of at least 3.3 eV. In one embodiment, the UV radiation is applied at an energy of at least 3.9 eV. In one embodiment, the UV radiation is applied at a dose and energy sufficient to break at least one of dielectric-hydrogen bonds, e.g., silicon-hydrogen and/or nitrogen-hydrogen bonds. In one embodiment, the UV radiation comprises a wavelength ranging from about 160 nm to about 400 nm." Column 10, line 50 through column 11, line 20 of Shiraiwa (emphasis added).

As stated in Shiraiwa, the "hydrogen content may range from greater than 3 atomic percent up to as much as 30 atomic percent, and in some cases may be greater than 8 atomic percent, and in other cases may range, from about 10 atomic percent to as much as 30 atomic percent." Column 10, line 65 through column 11, line 3 of Shiraiwa. One reason for this high hydrogen content is that Shiraiwa does not utilize the nitrogen radical process of the present invention. Regardless of the reason, Shiraiwa acknowledges that such hydrogen content of up to 30 atomic percent is high, but does not disclose any specific reduced level of hydrogen content that Shiraiwa does achieve. More particularly, Shiraiwa does not disclose that the hydrogen content is reduced to less than 1.0 atomic percent, or is reduced to between 0.0 and 0.5 atomic percent. Thus, Applicant submits that not only Shiraiwa is silent as to a nitride charge storage layer formed by nitrogen radicals, but also the Shiraiwa's nitride layer is patentability distinguishable since it does not achieve a hydrogen content less than 1.0 atomic percent, or between 0.0 and 0.5

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atomic percent, as disclosed and claimed by the present invention.

B. Conclusion


For the foregoing reasons, Applicant respectfully submits that claims 1 and 14 and dependent claims 2-6 and 15-19 are patentable over the art of record and as such the withdrawal of the finality of the present rejection and an early notice of allowance directed to claims 1-6 and 14-19 remaining in the present application are respectfully requested.

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Respectfully Submitted,
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